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An Application of Economics & Environmental Planning: The Impacts of Variable Rate Irrigation Technology on Net Farm Income

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The Impacts of Variable Rate Irrigation Technology on Net Farm Income

Hannah Jones University of Nebraska-Lincoln Professional Project

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ABSTRACT

Restoring playa wetlands back into predominantly agricultural landscapes has been a pressing issue for decades. The Nebraska Rainwater Basin Joint Venture (RWBJV) and its partners represent a wide variety of private and public groups who are offering solutions to this problem, while helping farmers maximize net farm income. The University of Nebraska-Lincoln partnered with the RWBJV on a project to determine how Variable Rate Irrigation (VRI) technology would impact the profitability of farm management operations, while allowing the preservation of adjacent wetland areas. This study conducted an economic analysis that compared net farm income for producers that had participated in wetland restoration and adoption of VRI.

Crop Enterprise Budgets were used to analyze the fluctuations in operational variables that may be affected by VRI. The feasibility of this technology was determined by using a discounted payback model with different levels of cost-share assistance over a two year period. The discounted payback model is a capital budgeting method used for determining the profitability of a project. The time it takes to breakeven on the investment is calculated while taking into account the changing value of money over time. This ensures that the producers have an accurate assessment of the true value of the investment at any point in time. Several scenarios were created to highlight how specific variables can greatly affect the model.

The results of this study show that this technology may be a feasible investment for some producers and not others because of the variability of each producer's situation. Due to unforeseen circumstances and outlying variables, some aspects of the analysis were invalidated. Although this meant that some benefits of the VRI technology could not be verified, there was still enough data to suggest the investment was warranted.

To allow for an expanded qualitative analysis of the data concerning certain uncontrollable variables such as market price, various payback models using historical trends for these variables were generated. These trends represent how net income from this investment would be affected in the future. Grazing infrastructure played a critical role in the feasibility of this investment. The benefits that were seen from this single resource were enough to potentially offset other setbacks and to give economic and environmental planners a powerful tool for convincing producers to participate.

Increasing the longevity and quantity of research studies similar to this will be necessary to determine what specific input cost variables are being effected by VRI in the future. What this study currently provides is a way to help environmental planners narrow the gap between agriculture and conservation.

Key Terms

Variable Rate Irrigation (VRI) Technology – VRI is precision irrigation that allows custom water application based on topography information, soil data maps, yield data, and other user-defined information (Evans et al., 2000).

Prescription Mapping – Prescription mapping uses electrical conductivity data to read the variability of the land and prescribe the correct amount of water, fertilizer, or seed that should be applied throughout the different zones within a field.

Wetland – A wetland is an area that is inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, a prevalence of vegetation typically adapted for life in saturated soils (Nebraska Wetlands, 2015).

NRCS – The Natural Resource Conservation Service provides technical assistance to farmers and other private producers and managers (The Rainwater, 2015).

WREP – The Wetland Reserve Enhancement Partnership offers incentives for producers to restore wetlands on their property located within the Rainwater Basin (The Rainwater, 2015).

RWBJV – The Rainwater Basin Joint Venture is a partnership that works to achieve habitat conservation through cooperation and sound science (About, 2016).

NRD – The Nebraska Natural Resources Districts were "created to solve flood control, soil erosion, irrigation run-off, and groundwater quantity and quality issues" (NRD History, 2018).

Payback Model – The discounted payback model is a capital budgeting method used for determining the profitability of a project. The time it takes to breakeven on the investment is calculated while taking into account the changing value of money over time.

Price Differential – In this research, the price differential is the net change in average net income per acre from pre to post-VRI.

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CHAPTER 1: Introduction

I. Nebraska Rainwater Basin Joint Venture Efforts to Restore Wetlands

Water is an essential resource for all life on Earth. The various waterways and water bodies determine the location, shape and population of every terrestrial habitat, and is an essential ingredient for all agricultural practices. Traditionally, one of the most undervalued forms of this resource is the wetland. Wetlands are "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support…a prevalence of vegetation typically adapted for life in saturated soils" (U.S. Army Corp of Engineers, 1987).

The non-monetary benefits these wetlands provide to the environment and producers are far too great to give a complete list here. Some of the most common biological benefits recognized by conservationists and land-use planners are providing a habitat for migratory waterfowl, inhibiting soil erosion and flooding, and enhancing water filtration. The problem is that most of these benefits are difficult to monetize, and often those profits are shared public goods or spread among future generations. This is because the public is willing to pay to support waterfowl habitats that might have tourism benefits, but returning those profits to the producer is difficult without easements which remove land from production. Management decisions in the Rainwater Basin (RWB) often do not reflect these values, since 90% of the wetlands are privately owned and the benefits do not accrue to the producer.

According to the interagency partnership known as the Rainwater Basin Joint Venture (RWBJV), "by the early 1980s, only 10% of the Rainwater Basin's wetlands remained" (Schildman and Hurt, 1984). Again, the problem here is that the biological services offered by the wetlands have traditionally been viewed as having little value compared to production. Even if it might be possible to conserve wetlands and receive a positive return from an easement, the return is often much larger for a sale to someone who intends to fill the wetland and produce crops. For conservationists trying to preserve or restore these wetlands, their efforts are complicated by the fact that approximately 90% of the land in the Rainwater Basin (RWB) is privately owned.

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One of the programs that has been created to help restore wetlands is the Wetland Reserve Enhancement Program (WREP). The WREP is a federal program that funds partnerships between the USDA- Natural Resource Conservation Service (NRCS) and a local partner.

The Rainwater Basin Nebraska WREP was developed through a partnership between the RWBJV and the local NRCS office to help meet the specific needs of RWB producers. In addition to several government agencies, the program involves several private companies (Cropmetrics, Lindsay, Reinke, and Valmont) that are working with producers and government agencies to develop and install irrigation technologies that are compatible with WREP.

According to the NRCS fact sheet for the WREP, "wetlands and upland habitats adjacent to, and within, pivot circles will be restored in the Rainwater Basin wetland complex" (The Rainwater, 2015). The fact sheet further explains that, "this project proposes restoring and protecting wetlands in an active agricultural landscape by allowing center pivots to cross wetlands, ensuring wetlands are compatible with the agriculture production in this region" (The Rainwater, 2015). This is extremely valuable given that about 2/3 of wetlands in the RWB are intersected by pivots. This means that enrolled acres provide the benefits of restored wetlands, but the program still provides producers with the ability to produce on adjacent land.

II. Introduction of Precision Irrigation Technology

An essential technology used to enable agricultural operations to occur adjacent to wetland areas is Variable Rate Irrigation Technology (VRI). It was initially developed to allow producers to increase crop yields through optimizing inputs and enabling operations on partial circles. VRI can be defined as applying "a precise amount of water at the correct time" throughout the field based on soil data maps, yield data, and other physical and biological field information (Evans et al., 2000). Prescription mapping is used to determine the amount of water that should be applied throughout different zones of the cropland based on soil and topographic conditions. VRI allows a pivot system to rotate over a wetland area without applying irrigation water, which reduces costs for the producer and conserves water. In addition to applying water more precisely, VRI can also be used for precise pesticide and fertilizer application. This allows producers to potentially save on non-water input costs, thus utilizing resources in a more sustainable and efficient way.

A unique aspect of the VRI technology used under WREP is that it can be equipped with specific wheels capable of floating or moving through wetland areas without destroying the integrity of the restored wetland. Lindsay Corporation, an irrigation company, offers a version of these wheels that provide "incredible traction, consistent performance and limits downtime, but also improves wheel tracking over standard pneumatic tires and solid wheel alternatives" (NFTRAX, 2017). Their product description explains that downtime is limited due to reduced maintenance from cleaning and tire change (NFTRAX, 2017).

What these tires have offered, are a way to restore wetland areas adjacent to productive lands without creating divots in the restoration area. Compared to other states, the WREP in Nebraska is unique in allowing pivots to cross wetland areas, which allows for greater flexibility to producers in deciding where to plant their crops around the wetland.

Fully understanding this technology could help Nebraska to step forward as a leader in wetland restoration efforts and precision irrigation technology, which may lead to other states adopting it in the future. With the WREP incorporating VRI technology into their conservation programs in Nebraska, it is likely that many other states will be interested in this innovative methodology as well.

III. Purpose of Research

To evaluate the economic impact of incorporating VRI technology into the WREP, the RWBJV applied for and received grant funding from the Nebraska Game and Parks Commission to complete an economic study. Dr. Karina Schoengold (Agricultural Economics) and I were hired to conduct an empirical study to analyze the economic viability of jointly using VRI precision irrigation with wetland restoration.

More specifically, I collected and analyzed financial and performance records from producers in the RWB. I analyzed financial data from two sites with restored wetlands and upgraded VRI pivot irrigation equipment to measure the effects of VRI technology and wetland restoration on net farm income. Grazing infrastructure was incorporated into the analysis, as producers with the necessary fencing can generate revenue by renting out the wetland area for grazing.

This research provided a unique opportunity to narrow the gap that has existed among conservation best management practices and precision irrigation technology within the environmental planning field. Therefore, one goal of the project is to measure net benefits from VRI. If VRI has a positive economic benefit, conservationists could use it as a tool to connect conservation and productive lands.

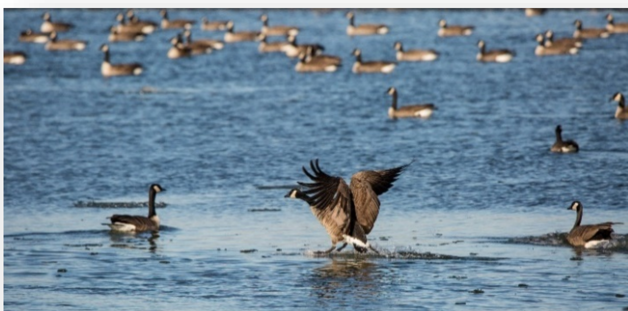
The biological benefits provided by restored wetlands have been well documented in existing research. However, quantifying these indirect benefits is difficult, and beyond the scope of the current project. Thus, any benefits from the current analysis should be considered a lower bound on the overall value of any project involving wetland restoration.

This research seeks to answer two related questions: (1) Does VRI technology provide WREP with a cost-effective method to irrigate areas adjacent to wetlands? (2) Under what conditions is VRI technology economically beneficial?

In order to evaluate the effect of VRI on net farm income, a variety of data was collected from the retrofitted sites with upgraded irrigation equipment and from reference sites (unaltered landscapes). Physical characteristics of the fields (e.g., soils, biological services, and habitat) ensured that the analysis compared similar fields. Other data was critical for the comparison of economic cost and returns on the test and reference fields.

Some of the necessary data included: historical data on yield, input costs associated with seed and fertilizer, maintenance, and annual crop insurance costs. Three to five years of historical data was requested from each participant in order to accurately assess the fluctuations in their net farm income.

The information on past revenues and costs was used to create an average net income to estimate the payback period for VRI technology used with wetland restoration. The average net income provided a benchmark to assess differences associated with wetland restoration and changes in practices on the associated crop acres. The discounted payback model is a capital budgeting method used to determine the profitability of a project. The methodology analyzes a potential investment while incorporating the changing value of money over time. This ensures that the producers have an accurate assessment of the true value of the investment at any point in time.



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Future returns were projected under a range of assumptions about future crop prices and weather conditions to show various scenarios for possible changes in net farm income. Results also compare alternative cost-share levels and discount rates for VRI technology adoption. Given that the useful life of a pivot irrigation system is approximately 15 to 20 years, it is critical that a shorter payback period is achieved to ensure the investment is profitable.

Other factors, such as producer's behavioral responses to change in crop or water prices, are not evaluated in this study due to the unpredictability of those assumptions and the difficulty of incorporating those factors into a quantitative analysis; however, they are considered in the discussion chapter.

Chapter 2: Literature Review

This literature review is divided into three sub-sections. The first section takes a global approach and examines findings from case studies of wetland restoration projects. The second section discusses the literature pertaining to wetlands in Nebraska, and the last section will look at literature pertaining to VRI precision irrigation technology.

I. General Wetlands

Previous research utilized existing wildlife habitat models to compare the net change in "four alternative landscape positions of wetlands within the Iowa watershed" (Otis et al., 2013). The four alternative landscape positions were: tile-zone (dominated by corn and soybean crops), breakpoint, and upstream and downstream floodplains.

The study found that "species richness and habitat availability for birds, mammals, amphibians, and reptiles increased" in the southern portions of the Iowa watershed compared to that of the northern areas (Otis et al., 2013). The northern portion of the watershed was dominated by cropland use and the southern portion consisted of "floodplain landscapes with more grassland and increased habitat diversity" which is the primary reason for the differences between the northern and southern areas of the watershed (Otis et al., 2013). Wildlife Habitat Relational Models were used to classify the amount of useable habitat for each species pre and post-wetland restoration which allowed them to account for species richness.

The models used in this case study provide evidence that location can be a primary factor for wildlife habitat choice and supports the fact that the NRCS and the RWBJV partners work together to identify stopover areas and the effects of landscape positions on wildlife habitat through use of habitat data collected annually.

Armstrong, et al. (2011) found that a lack of participation in the program stemmed from poor relationships among upstream-downstream producers. Inaction by upstream producers made it difficult for downstream farmers to maintain a viable conservation area. Additionally, resentment of government regulations regarding streamflow created an environment of distrust between producers and government agencies.

This article illustrates the point that producers upstream and downstream must work together and communicate to implement and achieve sound conservation goals. Agreements for each party to be accountable for their portion of conserving the land is critical for increasing adoption in conservation programs such as WREP. This is important in many restoration projects, as the difficulty in getting agricultural producers to see the value of wetland conservation has been hampered by the inability to allow any type of production near restoration areas. The gap of mistrust between government and private producers continues to be an obstacle for conservationists. This research could pose as a fundamental example of how conservation can be achieved without reducing the profitability of agricultural practices.

Kaza and BenDor (2013) study three counties in North Carolina between 2000 and 2007, and included all ecosystem restoration sites in these areas. When unrestored streams and wetlands were controlled, the study found that parcels of land "<0.5 miles away from Ecosystem Enhancement Program (EEP)" sites exhibited a decrease in property values compared to sites between 0.5 and 0.75 miles away which exhibited an increase in property values at "$11,780 and $8,345.70, respectively" (Kaza and BenDor, 2013). EEP sites are similar to restored wetland sites, but they can also include other types of ecosystems such as forests or grasslands.

This study concludes with recommendations for further research for "higher public visibility of aquatic ecosystem restoration programs," and discussed how increased public information could increase the value of properties near EEP sites when at certain distances from residential dwellings (Kaza and BenDor, 2013). Results show that the effect of wetlands on property values is non-monotonic, specifically, wetlands reduce the values of very close properties, but increase values for property that is further away (i.e., 0.5 to 0.75 miles). However, results vary by land use and type.

II. Nebraska Wetlands

The RWBJV Public Lands Workgroup surveyed public lands within the RWB between 2009 and 2013 to determine the various levels of vegetative communities. For waterfowl in the RWB, it is desirable to have “moist-soil dominated plant communities because of the large amounts of seeds produced, which are a high-quality waterfowl food” (Rainwater Basin, 2016).

The study found that grazing increased ponding frequency, created structural and species diversity, reduced stand height, and generated income for the producers involved (Rainwater Basin, 2016). Additionally, the study reported that “grazing in multiple, consecutive years increased its effectiveness” (Rainwater Basin, 2016). This shows that grazing opportunities can not only improve net income, but also improve the biological services that wetlands provide.

Poor (1999) examined the economic feasibility of “publicly funded wetland acquisition programs”. She used the contingent valuation method (CVM) to estimate the value Nebraskans place on wetland habitat. The results indicated a positive relationship between respondents’ willingness to pay for wetland services and those who had visited the RWB region (Poor, 1999).

Beas et al. (2013) evaluated if restored wetlands developed similar plant communities to that of reference wetlands post-hydrology restoration. A total of 34 playa wetlands categorized as restored, reference, or agricultural were sampled in the RWB between 2008 and 2009 (Beas et al., 2013). In 2008, the study found that “reference and restored wetlands had higher species richness and more native, annual, and perennial species than agricultural wetlands” but fewer exotic species compared to reference sites (Beas et al., 2013).

In 2009, “reference and restored wetlands had higher species richness, more perennial species, and more native species than agricultural wetlands” but restored wetland “contained a greater number and proportion of annuals than reference and agricultural wetlands” (Beas et al., 2013). This study concluded that restored wetland sites do not exhibit the same plant communities as reference wetland sites. They believe this may be attributed to seed bank communities between reference and restored wetlands, dispersal limitations of perennials, or management practices preventing restored wetlands from developing plant communities similar to that of reference wetlands (Beas et al., 2013).

In fact, research is being conducted in the University of Nebraska-Lincoln's Department of Agronomy and Horticulture to evaluate the ability for cattle to digest vegetation on wetland areas, making them even more appealing to producers who have the option to incorporate grazing into their operations. Grazing revenue could help alleviate some of the feed input costs associated with their cattle.

Belden et al. (2012) examined pesticide contamination in sediments from playa wetlands. This is unique compared to the previous literature that has focused on habitat or vegetation aspects of playa wetlands. This study selected 264 playa wetlands in the High Plains and RWB from three land-use types – cropland, perennial grassland enrolled in conservation programs, and native grassland. Soil samples were taken from 6 cm in three locations in each wetland and tested for agricultural pesticides – atrazine, acetochlor, metolachlor, and trifluralin (Belden et al., 2012). This study found herbicide concentrations that were hazardous to plants but insecticide and fungicides were rarely detected. Not surprisingly, pesticides were higher in wetlands surrounded by cropland compared to native grassland and CRP perennial grasses.

This article also showed the positive effects of CRP and other conservation programs. A majority of the wetlands adjacent to native grasslands or CRP lands exhibited little to no recognition of pesticides. This shows that these programs are proving successful in prevention of pesticide contamination, even in places downstream like the Rainwater Basin or High Plain wetlands in Kansas. The data provided in this case study could be "combined with other ecosystem service data to simultaneously evaluate the effects of conservation programs and land-use changes on sustainable provisioning of services to society" (Belden et al., 2012).

The current study will not analyze the effectiveness of the VRI technology in reducing runoff or improving ecological functions of adjacent wetlands. However, results from other research that evaluates this relationship suggest an additional benefit of VRI technology that should be considered in future studies.

Pimental et al., (2015) found that increased soil erosion by wind and water "adversely affects soil quality and productivity by reducing infiltration rates, water-holding capacity, nutrients, organic matter, soil biota, and soil depth". Additionally, when one of these factors are affected, the others are affected because they are all part of an interrelated system. The article created empirical models to assess how erosion rates and soil productivity are influenced by the factors listed above (Pimental, et al., 1995). The models show how soil erosion "causes the loss of soil nutrients, depth, biota, organic matter, and water resources" (Pimental, et al., 1995). The loss of water and nutrients in the soil accounted for 90% of the loss in crop productivity on agricultural lands that were evaluated.

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In the United States, the costs associated with the loss of productivity due to soil erosion amounts to $196 per hectare when assuming on-site and off-site costs (Pimental, et al., 1995). Around 60% of the soil lost from cropland each year is deposited in lakes and streams. This percentage has started to decline with erosion control technologies. The authors discuss the use of "ridge-planting, no-till cultivation, crop rotations, strip cropping, and grass strips" as ways to reduce soil erosion. These practices have been proven to substantially decrease the soil and nutrient loss each year in the United States.

The article concludes by estimating the cost of reducing soil erosion to a sustainable rate. The article notes that it would take "$6.4 billion per year ($40 per hectare for conservation) to reduce U.S. erosion rates from about 17 tons" to 1 ton per hectare per year on a majority of cropland (Pimental, et al., 1995).

This article demonstrates a method for determining the numerical value of providing services that are similar to those provided by wetlands. Even though wetlands may not be comparable to every situation discussed in the article, the study does give monetary values associated with general erosion control. Land-use planners could also use this information to help define the BMPs for a particular area.

Bartuszevige, et al. (2016) discussed the landscape design process and how there’s a gap that exists among conservation planning and implementation of those plans. The authors use a case study to show the different elements of the landscape design process and how implementation can be effective through sound conservation planning efforts.

In 2014, the Playa Lakes Joint Venture (PLJV) used the landscape design approach to update their conservation plan. They started the process by setting a goal with stakeholders which amounted to providing “20% of the available calories to migrating waterfowl as native food resources” through playa wetland areas (Bartuszevige, et al., 2016). The next step in the process was to evaluate the current landscape by identifying areas of concern for the region such as the accumulation of sedimentation in playas and agricultural production. Surveys were conducted to identify the available habitat and water variability in the study area. Once a thorough evaluation of the landscape was conducted, the PLJV started to generate conservation strategies by first presenting the results of the models to the management board.

Two strategies came from their discussions. The first was focused on “the need for clean water by town residents that playas can provide through recharge to aquifer and natural bacterial processes to remove contaminants” (Bartuszevige, et al., 2016). This initiative was able to address the social and economic implications behind restoring and preserving playa wetland areas. In this way, the landscape design process, “balanced the ecological need and societal valuation of playa conservation” (Bartuszevige, et al., 2016).

The second strategy was to incentivize agricultural producers to include wetland conservation into their operations to “help producers transition out of irrigated agriculture” in areas that were threatened by severe aquifer depletion (Bartuszevige, et al., 2016). This successful case study example helped show how landscape design can be used to “drive effective and efficient conservation action” (Bartuszevige, et al., 2016).

These last two studies are very useful for my research because they provide working examples of my primary research goal, which is to determine if conservation and precision irrigation efforts can be tailored to accomplish both economic and ecological goals in the RWB. Although their studies were on a larger scale than mine, they nonetheless demonstrate the important role planners may take as facilitators in discussions among stakeholders involved in these conservation efforts.

Although the core of this project is dealing with the direct effects of precision irrigation, I am still considering how precision agriculture and conservation programs can work together to achieve financial and conservation goals. The economic discussions in these articles also helped me to formulate how many of the societal benefits of wetland restoration efforts might be financially evaluated.

A study by D.J. Case & Associates (2014) included 13 focus groups with farmers and ranchers in 6 states throughout the Playa Lakes Region in 2013 (D.J. Case, 2014). The purpose of these focus groups were to understand producer attitudes, opinions, and willingness to participate in playa conservation (D.J. Case, 2014). There was a great emphasis put toward understanding the impediments for producers to adopt conservation practices and for ways that agencies could encourage and enhance conservation of playa wetlands on private lands. A majority of focus group participants said that they were not currently enrolled in playa conservation programs because of economic implications. Many participants felt that they could get higher financial returns from farming/grazing playas than they could from the program. Others felt that the maintenance required for conservation of playa wetlands outweighed the benefits (D.J. Case, 2014).

However, many participants who were enrolled in the program felt that it did provide them with a higher economic return than ranching and farming practices. Results also showed that some producers want to be part of the conservation programs for the wildlife, to rest the land, or for recreational benefits (D.J. Case, 2014).

The current project uses similar planning strategies to incentivize producers to enroll in playa wetland conservation programs. It also promotes cooperative relationships between public entities and private producers through cost-share programs that help to alleviate some of the costs associated with the upgraded equipment. Ultimately, the goal is to find a version of the precision irrigation technology that will allow conservation planners to not only encourage wetland restoration efforts, but also BMPs near these wetland areas.

III. Variable Rate Irrigation Technology

These articles will cover various aspects of VRI technology including the pros and cons, benefits to small farmers, funding opportunities, implementation strategies, and an economic analysis from an investment perspective.

Evans et al. (2013) discussed the limited research studies that have been conducted to provide evidence of the benefits of site-specific variable rate sprinkler irrigation (SS-VRI) technology. The authors explain that due to a lack of research and economic incentives backing up this new technology, few have adopted it throughout the world. The article goes on to provide examples of ways to increase adoption of this new technology. They recommend that tools for defining management zones and equipment are needed. Basic prescriptions, optimal placement of various non-mobile sensor systems, technical assistance and training, decision support, and education about available funding opportunities are also imperative (Evans et al., 2013).

They also suggest that an impediment to adoption is a lack of available irrigation prescriptions for humid and arid environments. The authors expect that increasing energy and water restrictions in the future will lead to shifts in the availability of irrigation prescriptions may be written to remedy the challenges posed in arid and humid environments.

The RWBJV partnership is promoting similar technology by offering programs that provide significant cost-share assistance to producers with an interest in VRI but find the cost prohibitive. The VRI technology allows producers to shut off irrigation application and chemigation on restored wetland sites.

Grisso et al. (2011) discussed the pros and cons of VRI used with map-based and sensor-based methods. Case studies from Lambert and Lowenberg-DeBoer were utilized to determine the economic findings from each study. Out of the 108 studies that were compiled, 63% of them indicated a positive net return for precision farming technology. Only 11% of those indicated negative returns, with 26% of them having mixed results (Grisso, et al., 2011).

The article suggests that a combination of map-based and sensor-based methods be used to achieve the greatest production and environmental efficiency in crop production. The study also points out that variable-rate application (VRA) methods are site-specific and that not every farm will show an economic benefit from these methods. It is necessary to be cautious of the conditions of the property prior to implementation of these methods and VRI technology. Although the majority of the participants in this large study showed positive effects on their net income, 37% had negative or mixed results. This suggests that experience with the technology is mixed, and may not be beneficial for all users. Prescription mapping is a way for software to read the land to determine the proper amount of water that should be applied based on soil and topographic conditions.

Hedley et al. (2010) utilizes “available water holding capacity (AWC) maps, generated from soil apparent electrical conductivity maps, with real time soil moisture monitoring” and wireless sensor networks (WSN) to evaluate the benefits of irrigated water (Hedley et al., 2010). They used a 111 hectare farm site with variable soil types under a linear sprinkler irrigation system for this study. A soil water balance model compared the VRI and uniform rate irrigation (URI) scheduling for 5 irrigation seasons and found that VRI reduced irrigation among soil zones with higher AWCs, where “soils have a greater ability to store and supply plant available water” (Hedley et al., 2010).

The average water savings from using VRI technology showed a mean of 5% or 26 mm/year from 2004 to 2009. The study made the assumption that if the “mean cost of irrigation was $2/mm/ha (FAR, 2008),” then the cost benefit would be “$52/ha/year” (Hedley et al., 2010). Additionally, the article demonstrated that in soil moisture deficient (SMD) zones with larger AWCs, VRI aims to “reduce drainage and run-off, minimizing the risk of leaching nutrients past the root zone” (Hedley et al., 2010).

The results of this study indicated that VRI technology can help prevent run-off and drainage of chemicals into nearby areas. It also helps to understand the specific details involved with savings on water input costs in specific soil types. This information will be helpful in explaining some of the mixed results that I obtained in my study.

LaRue and Evans (2012) analyzed the results of a field study in Dyersburg, Tennessee, and find that VRI Zone Control Packages could help compensate for improper irrigation application (LaRue and Evans, 2012). The packages used in this project were created by CropMetrics, the same company that provided irrigation prescriptions to the producers in the current study. CropMetrics uses electrical conductivity (EC) mapping for irrigation prescriptions to help improve yield through proper speed control, section zoning, and irrigation scheduling.

More specifically, this company uses EC mapping data to show the physical and chemical properties of the soil in a field and write irrigation prescriptions based on this information. The mapping indicated a field variability rate of 26.7%, which means that only three-quarters of the field was being optimally irrigated. Therefore, implementing these prescriptions are likely to improve water application.

An NRCS report used case studies to evaluate the reliability and return on investment of VRI systems. One study in South Georgia found that "5.7 million gallons of water were saved on 279 acres in 2002" (Precision, 2007). The other study on an Idaho potato farm found that the cost of the variable rate system was not justified by the minute increase in yield and savings in water. Perhaps, this illustrates one of the drawbacks of VRI systems, that every field is variable and may yield differing results. Additionally, in 2007, the average cost to retrofit an existing pivot system with VRI equipment was $15,000 (Precision, 2007).

Planners that wish to help producers make decisions regarding precision irrigation technologies, should partner with other irrigation experts to consider the possibility of providing cost-share assistance options for prescription mapping prior to making the decision to adopt. This would help alleviate some of the risk involved and may result in many producers choosing VRI without cost-share assistance if the mapping shows they are likely to receive a worthwhile benefit.

Mitchell and Johnson (2001) discussed the protection of prime farmland being converted to non-agricultural uses and the value of conservation easements in this process. Some of the advantages of conservation easements are that the land remains in private ownership, it can increase the value of surrounding land where open space is desired, and potentially provide some tax breaks. Some of the disadvantages include: reduced property value due to loss of crop production, competition among funding opportunities, and in order to receive tax benefits one must have a conservation easement that runs in perpetuity (Mitchell and Johnson, 2001). One method used to appraise conservation easements is the comparable sales method which uses "actual sales of similar easements to compare to the easement being appraised" (Mitchell and Johnson, 2001). Another method is the "before-and-after easement sales method which takes the full value of the land before the easement is placed on it and subtracts the value of the land with the easement" (Mitchell and Johnson, 2001).

Almas, et al. (2003) examined the investment costs of VRI technology in Texas, the breakeven variability and yields of grain crops to offset the cost of the technology (Almas et al., 2003). A cost-benefit analysis was conducted to determine the feasibility of VRI. Crop input costs and fixed investment costs were considered for this analysis. Average crop prices according to local markets were obtained and "the future streams of returns over five years were discounted to present value (PV) using a discount rate of six percent and compared with the initial cost for investing in the technology" (Almas et al., 2003). If the PV was found to be greater than the investment costs, then adoption of the precision agriculture technology would be a wise choice. The study stressed the importance of yield maps for each crop in each zone of the field to determine if VRI would be suitable for implementation. The study found that feasibility of VRI technology was reliant upon field variability, crop value, economies of scale, and the useful life of the equipment. In the case of a field having problems with irrigation nozzles rather than yield deviations, VRI may not help to improve net income, however, in the case of a field with high variability and problems with achieving yield goals, VRI may be a better option.

Castle (2016) used fixed panel data models to determine the economic impact of using precision agriculture technologies by collecting financial data from 59 producers across Nebraska between the period of 1995 to 2014 (Castle, 2016). There were many technologies surveyed in this study, including variable rate application of water, nutrients, and seed planting (Castle, 2016). Even though the precision agricultural technologies used in this study are varied, among them was VRI (i.e. automated section control). The author notes that one obvious answer through the data collected in the study was that increased experience with these technologies appeared to increase profitability margins (Castle, 2016). Therefore, the results of this analysis, showed the “existence of a strong, positive relationship between number of technologies used and net farm income, indicating that precision agriculture use is associated with higher profitability” (Castle, 2016).

This study is relatively new and shows that there is potential to increase profitability by using more precise agricultural technologies. Although the author admits that there is not enough statistical significance in the data variables to prove that precision irrigation technologies are the cause of the observed increased profitability; there is nonetheless, an increase in profitability that is correlated with those using these technologies. He also suggests that increased experience with these technologies improves the profitability margin further.

The author concludes that there is a lack of research, “using real-world financial data to examine the realized impact of precision agriculture” (Castle, 2016). The current study adds to the literature addressing this topic.

CHAPTER 3: Methodology

This study used the financial and performance records from producers in the Rainwater Basin with restored wetlands and upgraded pivot irrigation equipment with reference sites to determine the effect of the restoration and VRI upgrade on the producer’s net farm income. The comparison includes the potential for grazing income from wetland areas, which is a good strategy to earn revenue, and an essential activity to control vegetative growth. The methodology also includes any savings associated with reduced feed input costs, energy, and water costs when applicable. As part of the restoration project, both wetlands were enrolled in the Wetland Reserve Enhancement Program (WREP).

A breakdown of the partners in this research are in Table 3.1. Through cost-share assistance, these partners have helped reduce the financial burden associated with the VRI upgrade.

Table 3.1 Partners in this Research

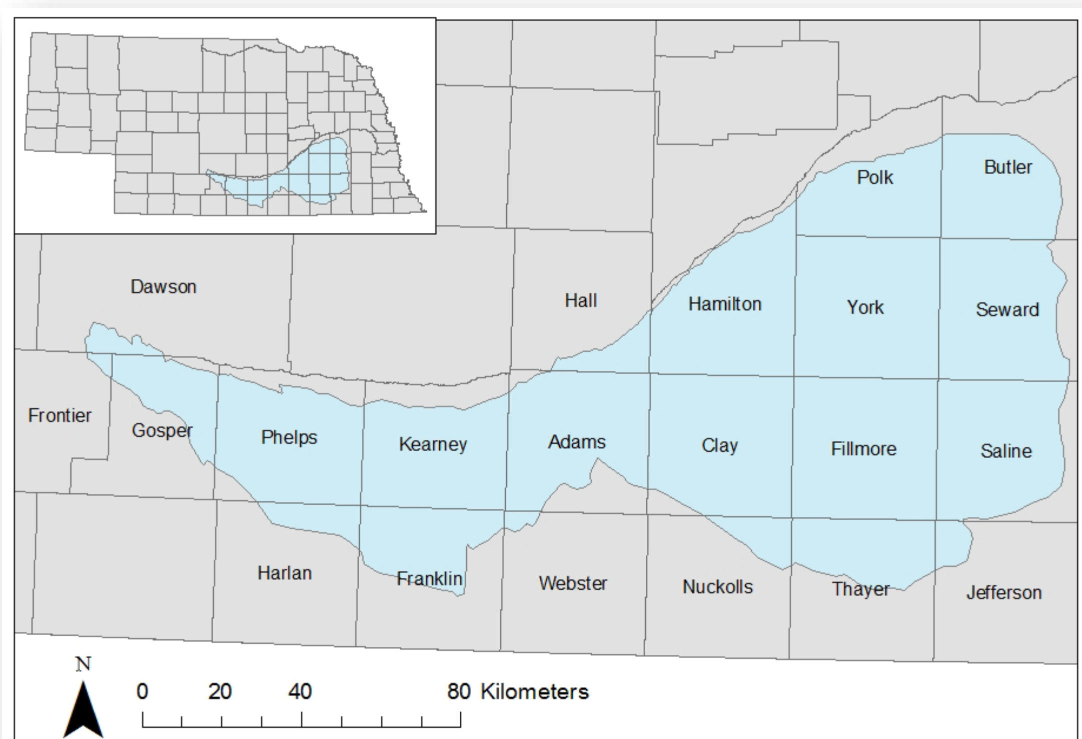
List all partners involved in this grant and their contribution to the project.

Partner	Contribution
Rainwater Basin Joint Venture	The RWBJV will provide the partnership support structure to oversee the administration and coordination of this grant. The RWBJV has a full-time coordinator who will be responsible for this grant. The RWBJV also has a Science Coordinator and GIS Specialist that will work with the partners to run the models and identify high priority eligible producers. This is an in-kind contribution.
Natural Resources Conservation Service	The NRCS will provide an agronomist that will provide the producer with technical support to use the soil moisture probes and VRI technology. NRCS engineers will help design the VRI system and complete the topographic survey for the wetland restoration design phase. A NRCS soil scientist will complete the soil survey that will be part of the wetland restoration. Funding through the NRCS Agriculture Conservation Easement Program will be used to purchase the easement and cover restoration costs. This is cash match.
U.S. Fish and Wildlife Service **Partners for Wildlife**	The U.S. Fish and Wildlife Service will provide in-kind biological and program expertise in designing the wetland restoration. The U.S. Fish and Wildlife Service will provide cash match as cost-share for establishment of the grazing infrastructure.
Natural Resources Districts	All of the Natural Resource Districts in the RWB provide cash cost-share for soil moisture probes. NRD staff also provides technical support during wetland restoration design. This is an in-kind contribution. Exact Natural Resources District will be determined by project location.
Nebraska Game and Parks Commission	The Nebraska Game and Parks Commission will provide in-kind biological and program expertise to the bio-engineering teams.
Landowners	Landowners will participate as members of the bio-engineering team, will provide ongoing maintenance, and will share provide 15% cash match for the VRI and development of the grazing infrastructure. Many of the landowners in the RWB, who have completed projects allow the RWBJV partners to highlight their projects during wetland tours with other landowners and policy makers.
Ducks Unlimited Inc.	Ducks Unlimited will provide in-kind biological and engineering assistance to restoration projects and cash cost share for the establishment of the grazing infrastructure.
Nebraska Environmental Trust	Through a grant awarded to the RWBJV the Nebraska Environmental Trust will provide cash contribution to both the wetland restoration and grazing infrastructure development.
University of Nebraska Lincoln	Dr. Karina Schoengold will oversee the economic assessment to evaluate the effects of wetland restoration and adoption of VRI technology on net farm income.
Cropmetrics, Lindsay, Reinke, Valmont	These cooperate sponsors have agreed to provide 10% cash contribution to the project. The type of pivot will determine which cooperate will contribute to the project. Having all major pivot manufactures as a partner ensures we will be able to work with any landowner in the RWB.

Note 1 Source: Andy Bishop. "The Economics of Wetland Restoration." (2015). Rainwater Basin Joint Venture & University of Nebraska-Lincoln. Nebraska Natural Legacy Project Partnership Team Innovation Grant Proposal Application 2015. p. 4.

In order to maintain confidentiality, the two participants that received the retrofitted irrigation package are referred to as Producer 1 and Producer 2. Producer 1 is located in Hamilton County and Producer 2 is located in Kearney County (Figure 3.1). Figures 3.2 and 3.3 show an aerial view of each parcel and the restored wetland areas. Producer 1 had the wetland restoration completed in 2013; whereas, Producer 2 had their wetland restoration completed in 2015. Both producers leased the cropland areas from the owners. However, Producer 1 also leased the conservation acres, which generated additional revenue; whereas; Producer 2 did not rent the conservation acres. Physical and biological characteristics associated with each producer's property are summarized in Table 3.2 below.

Figure 3.1 Nebraska Counties within the Rainwater Basin Complex Area[1]



Note [1] Source: Rainwater Basin Joint Venture. (2017). Rainwater Basin Joint Venture.

Table 3.2 Summary of Physical & Biological Characteristics for Producers 1 & 2

Characteristic	Producer 1	Producer 2
Pivot Acres	243	105
Area	260.33	173.77
Predominant Soil Types[1]	Scott, Butler, & Fillmore	Scott, Fillmore, & Massie
Maximum Ponding Frequency[2]	0.91	0.73
Crop History	Corn	Corn, grassland, pasture

Note 1 Predominant soil types are those that make up a majority of the types of soil found on this parcel of land.

Note 2 Ponding frequency is based on a scale from 0 to 1; with 0 being dry and 1 meaning 100% of the year the wetland footprint area is saturated.

Figure 3.2 Aerial map of Producer 1 Property in Hamilton County[1]

Note 1 Source: This map was produced by the Rainwater Basin Joint Venture Partners for Fish and Wildlife Program Producer Agreement.

Figure 3.3 Aerial Map of Producer 2 Property in Kearney County[1]

Note 1 Source: This map was produced by the Rainwater Basin Joint Venture Partners for Fish and Wildlife Program Producer Agreement.

The preferred way of estimating the impact of VRI and wetland restoration on the participants net income is to compare their data with control sites that are similar except that they haven't adopted VRI. Science Coordinator Dr. Dana Varner used spatial queries in Geographic Information Systems to identify sites with specific wetland characteristics (e.g., soil type, wetland footprint size, ponding frequency); and the proximity to the reference sites. Three of the identified participants agreed to take part in the study. The invitation letter and data collection form used to contact and collect their information can be found in Attachments A and B in the Appendix. The three control participants submitted data for 2014, 2015, and 2016. Unfortunately, the available control sites did not serve as reasonable comparisons to the retrofitted sites. This is discussed in further detail in Chapter 4 below.

I. Data Collection

The data collection form (on paper and interactive) included questions about land use, production costs and returns, grazing infrastructure costs, machinery, irrigation input costs, and annual management and overhead costs. Although the precision irrigation technology was expected to have a direct effect on specific variables like applied water and fertilizer input costs, other information is critical to estimate a complete economic enterprise budget, including variables like energy costs that may change after the restoration and retrofit.

Two years of data were collected from the retrofitted Producers 1 and 2 prior to the VRI upgrade, and two years post-upgrade to use for comparison purposes. Therefore, data from 2014 and 2015 was used to compare with 2016 and 2017 to indicate the effects VRI had on net income. The Microsoft Excel crop enterprise budgets used in this study were created by Enterprise Budget Analyst Dr. Roger Wilson of the University of Nebraska – Lincoln's Department of Agricultural Economics. An example of the budget tool used in this analysis is in Attachment C in the Appendix. The revised crop enterprise budget allowed us to estimate the effect of a range of input costs on net farm income, and to calculate the breakeven point for each crop. Furthermore, the budgets can be used to estimate the impact of changes in variable input costs (i.e. market price and yield) on the payback period for VRI.

Data from the USDA-National Agricultural Statistics Service and the Nebraska Department of Natural Resources was used to create a Market-Yield Matrix (Table 3.3) with low, average, and high values of yield and market prices between 2000 and 2016 in Nebraska. This data was used in the analysis portion of this project to predict how the payback on the investment would be affected by yield and market fluctuations.

Table 3.3 Corn Market-Yield Matrix

		CORN MARKET[1] PRICES[1]		
		Low	Average	High
Y	Low	\$1.90 180 bu./ac	\$4.34 180 bu./ac	\$6.67 180 bu./ac
I E	Average	\$1.90 191.7 bu./ac	\$4.34 191.7 bu./ac	\$6.67 191.7 bu./ac
L D	High	\$1.90 207.1 bu./ac	\$4.34 207.1 bu./ac	\$6.67 207.1 bu./ac

Note [1] Source: “Statistics by Commodity.” (2017). United States Department of Agriculture. National Agricultural Statistics Service. Available: <https://www.nass.usda.gov/Statistics_by_Subject/index.php?sector=CROPS>.

The discount rates used in this analysis are 3, 5, 8, 10, and 12 percent. The discount rates are a way to take into account the changing value of money over time. The different discount rates were chosen to illustrate a range of possible preferences regarding the devaluation of money and the riskiness of future earnings. This is distinct from the depreciation of the equipment, which takes into account the loss of value of a capital good overtime. While we include a range of discount rates to compare outcomes, other studies (e.g., Almas et al., 2003) use a single discount rate to estimate a payback model for precision irrigation technology.

The cost-share ratios used to calculate the discounted payback period are shown in Table 3.5. Cost-share agreements are commonly used by government agencies and conservation groups to reduce the participant cost of installing a conservation practice. The producers in the current study had a cost-share ratio of 85/15, which means that the producers provided 15 percent of the cost of the retrofit. A lower cost-share ratio for the RWBJV and partners would allow agencies to install conservation practices on more fields.

Table 3.4 Cost-share Assistance Levels used in Analysis

Cost-share Ratios (RWBJV Partners/Producers)
85/15
80/20
75/25
60/40
50/50

The participants provided additional qualitative data on their experience with VRI technology, wetland restoration efforts, and the feasibility of the technology (i.e. soil probes, cropping data systems) for their operation. Detailed observations are summarized in Section F of the next chapter.

CHAPTER 4: Results & Discussion

This chapter will begin with a discussion of the results from the two retrofitted sites, followed by a discussion of a comparison of their yields, including projections using the matrix in Table 3.3 and additional hypothetical scenarios.

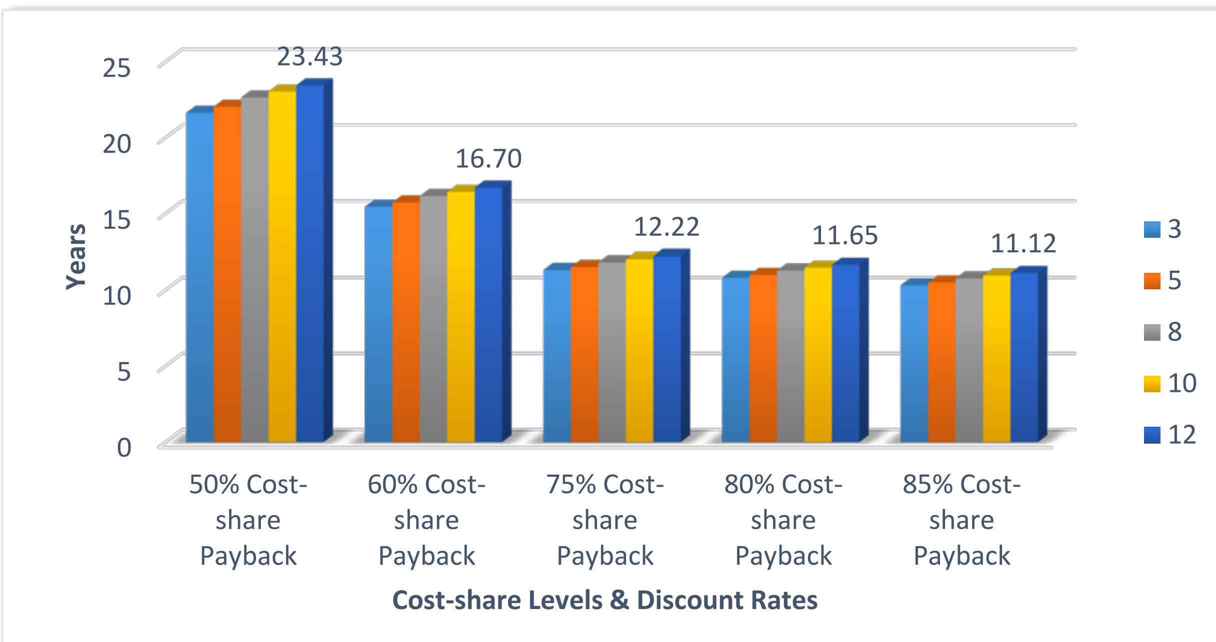
In order to estimate the feasibility of investing in VRI technology with adjacent wetland restoration efforts, the discounted payback model, annualized rate of return, and a range of market and yield conditions are used. For consistency, all of the analysis is conducted on a per-acre basis. The cost-share levels paid by the RWBJV partners and producers are based on the total cost of the project. As the project cost varies by the producer who obtained the retrofitted equipment, the necessary revenue to pay back the investment varies. The data from the control sites was inadequate to compare with the participants. Thus, we use pre-VRI and non-VRI data from the participants as control observations.

I. Payback Based on 2017 Corn VRI Data for Producers 1 & 2

Figures 4.1 and 4.2 show the payback period for the VRI investment for a range of discount rates and cost-share levels. The analysis is based on the difference between the per-acre profit with VRI technology and without VRI technology, and incorporates all operational changes due to the VRI technology and wetland restoration (e.g., grazing revenue). The analysis used data from corn production in 2017 from Producers 1 and 2, respectively. At the current cost-share level, the pay-back period for the investment is 11 and 6 years, respectively, for Producer 1 and Producer 2. Other cost-share levels show a payback period of 11 – 23 years for Producer 1, and 6 – 13 years for Producer 2. Since the useful life of a pivot irrigation system is approximately 15 to 20 years, this short payback period creates an economic benefit for these producers.

Because Producer 1 had fields in VRI and non-VRI with the same crops, the non-VRI field provided an excellent control site for the VRI field. Figure 4.1 uses a price differential of $23.00 per acre to represent the difference between the VRI and Non-VRI net income for Producer 1 (VRI = $34.00 and Non-VRI = $11.00). This price differential is due to grazing revenue generated in 2017.

Figure 4.1 Producer 1 Payback Based on 2017 Corn VRI and Non-VRI Data

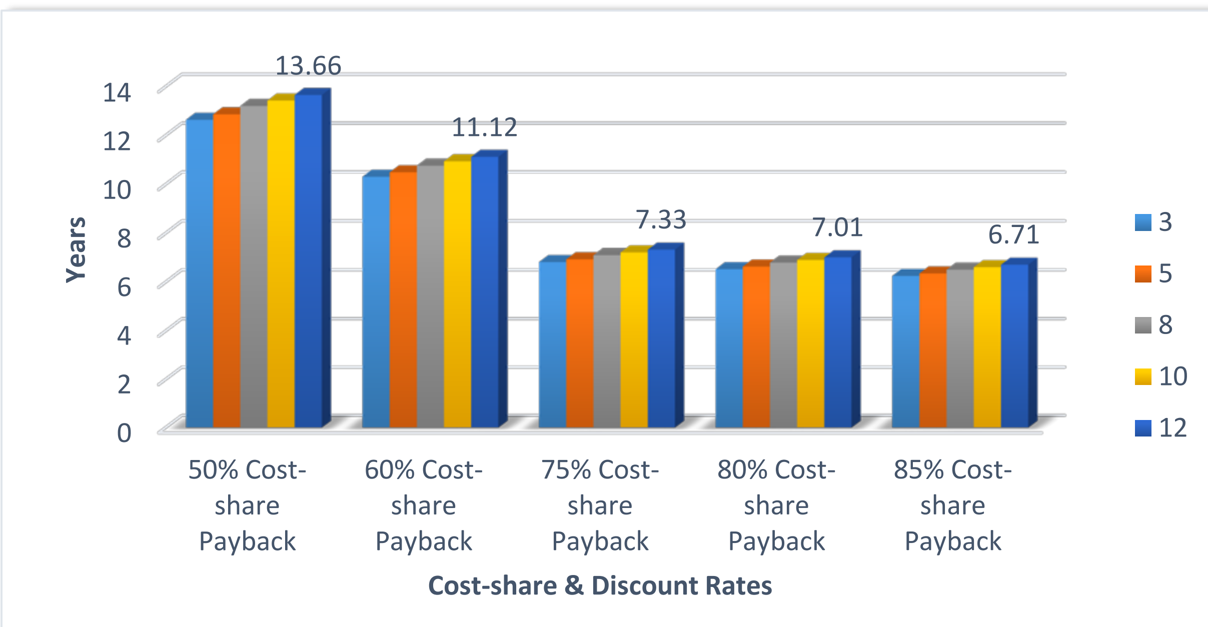


One way to measure the impact of VRI is to compare producer revenue before (2014 and 2015) and after (2017) the system was installed. Under this measure, both producers showed a loss, primarily due to low market prices for corn in 2017. If market prices were closer to the average market price in Nebraska between 2000 and 2016 (i.e. $4.34 per bushel), this loss would not have occurred. These issues will be examined in more detail below, after a brief description of how the price differential for Producer 2 was calculated.

In contrast to Producer 1, Producer 2 does not have a non-VRI field that can be used for a control site. The net revenue from Producer 1's non-VRI field is a poor control for Producer 2, since each producer reported different costs. However, each producer reported costs consistently over time. So, we compare the change in the per-acre profit for Producer 1's non-VRI field with the per-acre profit for Producer 2.

This price differential was calculated by averaging the pre-VRI (2014 and 2015) net income per acre and comparing it to the net income per acre in 2017. The net change was compared to the same net change for Producer 1's non-VRI field. The net income with VRI (in 2017) for Producer 2 was 27.4% of the average net incomes from 2014 and 2015; whereas, the 2017 net income for Producer 1 was 9.2% of 2014 and 2015 returns. Even though both producers had lower income in 2017 than 2014-2015, the decrease was lower for Producer 2 (VRI) than for Producer 1 (non-VRI). Using this method, we calculate a benefit of $33.81 per acre for Producer 2.

Figure 4.2 Producer 2 Payback Based on 2017 Corn VRI Data



II. Examining Potential Variables in Yield & Market Price

Table 4.1 and Figure 4.3 show the difference between Producer 1's non-VRI field and Producer 2's field. With the exception of 2016, Producer 2 consistently has higher yields than Producer 1.[1] While Producer 2's yield is higher in 2014 and 2015 (3.65 and 10.8 percent, respectively), the difference is much larger in 2017 (after VRI is installed). This is consistent with more precise application of irrigation water and fertilizer. Producer 2 had an increase in corn yield between 2015 and 2017 of 5.08 percent (236 and 248 bushels per acre, respectively). This increase occurred despite lower precipitation in the 2017 growing season (Statistics, 2017). While this may be attributed to other factors than just the VRI technology, it does suggest a potential benefit from VRI.

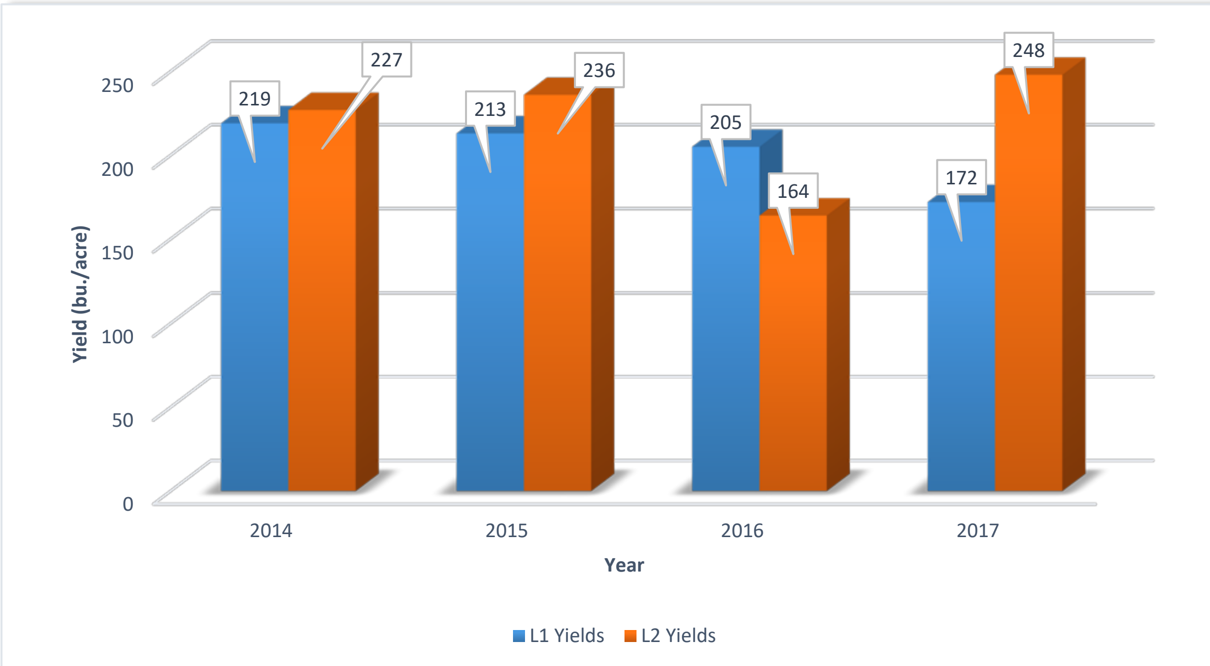
Table 4.1 Percent difference in yield between Producer 1 Non-VRI acres and Producer 2 VRI acres over the period of 2014 to 2017

Year	Percent Difference between L1 & L2
Pre-VRI 2014	3.65%
Pre-VRI 2015	10.80%
Post-VRI 2016	-20.00%
Post-VRI 2017	44.19%

Note: A positive value indicates that Producer 2's VRI field had a higher yield than Producer 1's non-VRI field.

[1] Producer 2 planted a hybrid seed that produced poorly in 2016.

Figure 4.3 Corn Yield Differences between Producer 1 Non-VRI Acres and Producer 2 VRI Acres



Producer 2 reported a market price of $3.10 and 248 bushels per acre yield for corn in 2017. With corn commodity prices at low levels compared to historical data, it suggests that it is reasonable to assume a higher price for the payback model. Incorporating an increase of 10 percent in both the price and yield ($3.41/bushel and 272.8 bushels/acre, respectively) into the payback models shows a large change in the result. The result shows an increase in net income per acre from $51.00 to $212.00. This increases the difference between VRI and non-VRI fields to $65.03, lowering the payback period for the investment from a range of 6 – 13 years to 4 – 7 years. An analysis that uses average price and yield information for a 10-year period (see the price-yield matrix in Table 3.3) shows a similar result. Based on the average values of $4.34 per bushel and 191.7 bushels per acre, the net income per acre increases from $51.00 to $114.00.

For Producer 1, the difference between the results and the average yield and price is even more dramatic, as the results were comparable to the low end of the corn matrix. Therefore, there is likely to be an increase in both price and yield on average in the coming years. To understand how significant this is, the producer's market price from 2017 is increased by 10%, which results in an increase from \$11.00 to \$345.00 net income per acre.

Comparing the recorded corn market prices for 2017 of \$3.10 and \$2.99 for Producers 1 and 2 respectively with the historical average of \$4.34, it is reasonable to assume that future prices will more often be higher. As long as yields stay relatively close to the average of 191.7 bushels per acre, the results suggest that VRI is a profitable investment at current cost-share levels for either producer.

The importance of exogenous variables such as market price on the results demonstrates the difficulty in accurately predicting all of the potential effects on net income in a given year. Maintenance costs were another variable that significantly affect net income. Producer 1 reported large maintenance costs in 2017 that reduced the per-acre profit of his operation. While the mechanical problems were unrelated to the VRI technology, incorporating those costs across all production acres reduces the profit for all fields. So, while these costs affect the overall profitability of the farming operation, they do not affect the differential between the VRI and non-VRI fields. Producer 2 did not report significant maintenance costs in any study year.

III. Scenario 1: Producer 1 Using Same Irrigation Energy Source for VRI Acres & Non-VRI Acres

One of the expected outcomes of VRI technology is lower energy costs for pumping groundwater, due to more precise application of irrigation inputs. Interestingly, this benefit is lower than expected for Producer 1 due to multiple sources of energy, with different costs, for groundwater pumping. Recall that the benefit of VRI technology for Producer 1 compares his non-VRI field with his VRI field. In 2017, both fields have corn, but the non-VRI field uses natural gas and the VRI field uses electricity. In 2017, the cost of pumping an acre-inch of irrigation water was higher with electricity than with natural gas, thus, this reduces the estimated benefit of VRI. To address this, we include a scenario where all energy inputs are priced based on natural gas. This increases the per-acre profit differential by \$24.00.

This highlights the value of this type of analysis in helping producers make informed decisions about their operations. Not only does this reasoning help to see past the limitations in the data, it also is a tool that can be useful for producers to analyze the fluctuations in various cost inputs which could affect their net income.

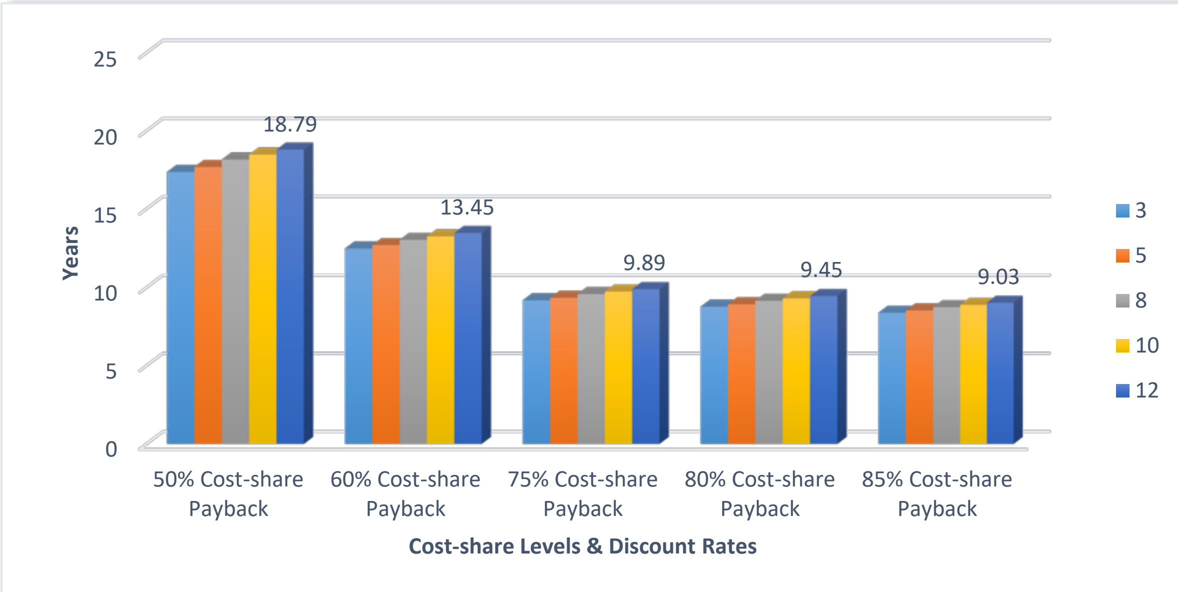
IV. Scenario 2: Producer 1 Reduced Irrigation Application

Since most producers have to pay for their water through the energy inputs needed to pump the water, it is important to consider whether or not VRI can lower the amount of water used. Reducing water use directly reduces energy input costs. While the data we collect does not show a change in water consumption, this is complicated by the short post-VRI period and the high amount of precipitation in 2017. Thus, we want to estimate how the results will change if VRI technology reduces irrigation water applied, relative to non-VRI.

According to Castle (2016), surveys with Nebraska producers have suggested that experience with precision irrigation tended to improve the ability to fine-tune the operation to optimize results. Therefore, it is reasonable to expect that over time, farmers will learn to use prescription maps for VRI and reduce their irrigation application. Other studies (Hedley et al., 2010; Grisso et al., 2011) show that the reduction in water use associated with VRI technology varies by soil type and condition. Given the range of results with respect to reduced irrigation application, we use a 20% reduction in applied water as an estimate of the future potential savings.

The post-VRI year (2017) had relatively high precipitation, thus, Producer 1 applied 2.25 inches per acre. A reduction of 20% (to 1.8 inches per acre) reduces energy costs, and increases the price differential \$23.00 to \$29.00 per acre. This is illustrated in Figure 5.4 which shows that the payback is decreased from a range of 11-23 to 9-18 years.

Figure 4.4 Scenario 2 – Payback Model Based on 20% Reduction in Irrigation Application on VRI Acres in 2017



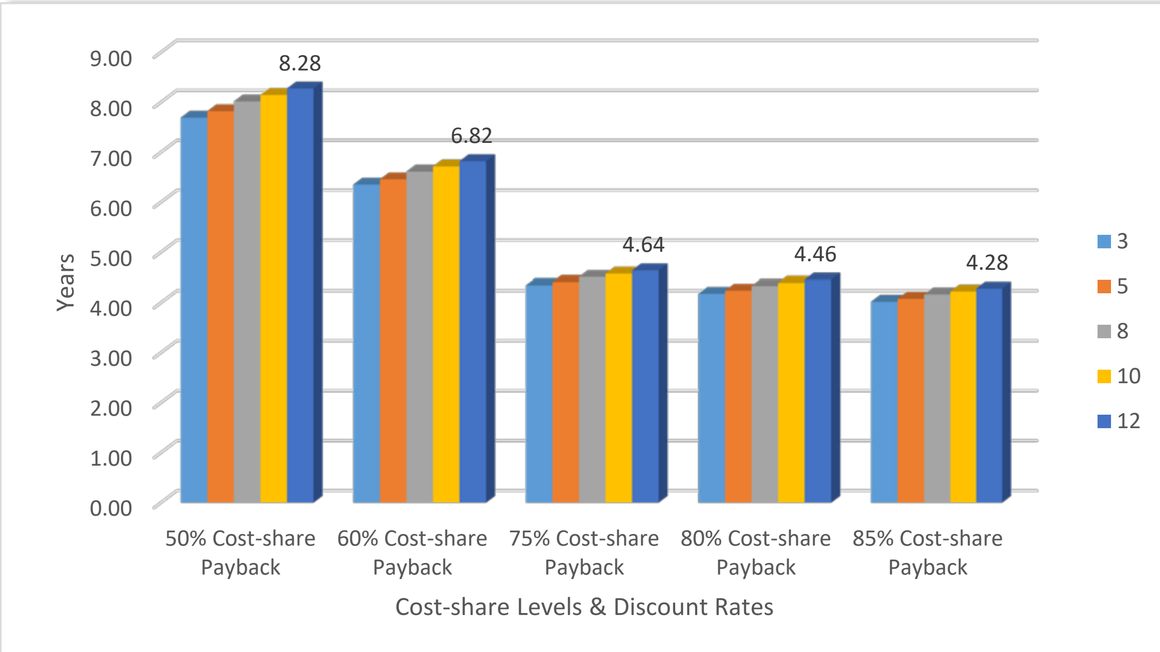
V. Scenario 3: Grazing Opportunities

In both cases, grazing infrastructure was implemented in the wetland restoration process. The size of the wetland restoration was 55 and 70 acres for Producer 1 and 2, respectively. Since Producer 2 leased 105 cropland acres, but did not lease the 70 restored wetland acres, his budget does not reflect the 2017 grazing income of $2,640. In this set of scenarios, we evaluate the VRI benefit if Producer 2 earned the grazing revenue, and we consider alternative ratios of wetland to cropland acreage. Since grazing revenue is based on the size of the wetland, a larger wetland restored increases grazing revenue, but reduces crop revenue due to fewer acres in crop production. The net effect of this depends on the relative profitability of these two sources of income. When market prices for crops are low, as they were in 2017, the benefits from grazing may be higher than the profit from crop production.

Scenario 3a

Producer 2 did not receive the income for grazing that was generated. If he had earned the $2,640 in 2017, the results would be as indicated in Figure 4.5, which reflects about a 30% decrease in the payback model. When that additional revenue is applied to the enterprise budget, the net income is increased from $51.00 to $76.00 per acre for Producer 2. This increases the price differential from $33.81 to $58.81 per acre when compared to Producer 1's non-VRI acres.

Figure 4.5 Scenario 3a – Producer 2 Payback with Grazing Revenue



This clear benefit from grazing shows that this aspect of the WREP is an integral part of making the investment worthwhile for participants who are able to take advantage of this opportunity. Apart from the value to this project, this aspect of the relationship between the restored wetlands and the productive lands provides a valuable tool for land-use planners that are looking for ways to convince producers to integrate land uses. This benefit is not just financial, as the environmental benefits of wetlands are significantly enhanced when controlled grazing is used to manage plant growth.

D.J. Case & Associates (2014) published a study done through focus groups with farmers across 6 states in the Playa Lakes Region where many of the respondents felt that the returns from the conservation programs were not as good as they were from farming and grazing that land. If other conservation programs allowed grazing on the wetland areas, participating producers would have another way to increase returns, and may be more likely to participate in wetland restoration.

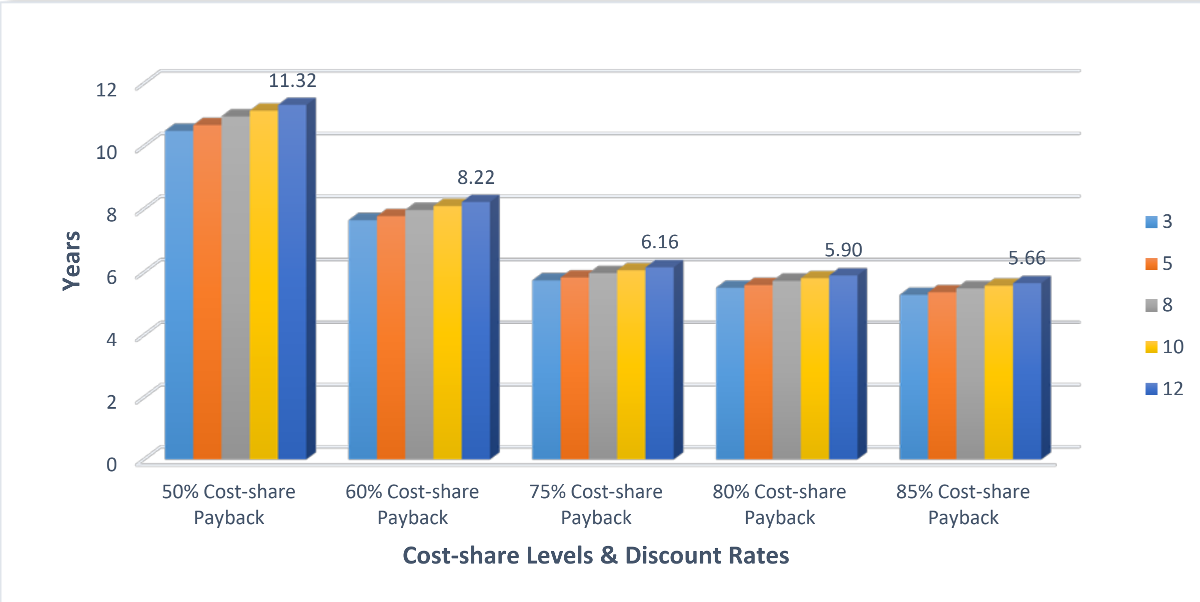
Scenario 3b

Originally, Producer 1 earned $4,230 from grazing revenue in 2017, providing a per-acre benefit of $42.30 on VRI cropland acres (Table 4.3). We want to compare the net income if the ratio of cropland to restored wetland changes, conditional on the same per-acre profit for each activity. For example if the size of the wetland increases from 55 to 75 acres (with a corresponding decrease in crop acres from 100 to 80 acres), it generates an additional $1,537.50 from grazing. This increases the per-acre crop benefit of grazing from $42.30 to $72.09 when allocated toward 80 VRI acres. Incorporating this increases the per-acre net income from $34.00 to $61.00, resulting in a VRI to non-VRI price differential of $50.00. Figure 4.6 shows that this reduces the payback period from 11 – 23 years to 5.7 – 11.2 years.

Table 4.2 Producer 1 Alternative Grazing Opportunities with Different Ratios of VRI and Wetland Acres

VRI Crop Acres	Conservation Acres	Grazing Revenue	Per Acre Crop Benefit	Per Acre Net Income
100	55	$4,230.00	$42.30	$34.00
80	75	$5,767.50	$72.09	$61.00
60	95	$7,305.50	$121.76	$108.00

Figure 4.6 Scenario 3b – Producer 1 Alternative Grazing Opportunities with 80 VRI and 75 Wetland Acres



This scenario shows that the variability in market and climatic conditions could be compensated by increasing grazing infrastructure. In addition, there is less variability in leasing rates which do not change considerably from year-to-year relative to crop prices (Jansen, 2017). This is important for producers to consider when making informed decisions about adopting additional wetland acres. It can also help to alleviate some of the cost burden associated with the first few years when producers are learning how to optimize the technology and improve their results.

Notably, the analysis above does not include the value of the environmental benefits associated with wetland restoration. The RWJBV Public Lands Workgroup finds that grazing not only generates income, but it also reduced standing height, increased ponding frequency, and helped to create structural and species diversity (Rainwater Basin, 2016).

Perhaps more importantly for planners is the fact that this gives them another option for earning revenue from land without producing on it. Mitchell and Johnson (2001) discuss strategies for evaluating easements to get a value from the land that is comparable to production values. If grazing infrastructure was included in the easement, it would likely make conservation more attractive to producers. As many easements make restored sites eligible for tax breaks, it makes the idea of increasing the size of the wetland area even more appealing.

VI. Qualitative Data

In addition to the budget information, we collect additional qualitative data from Producers 1 and 2. Specifically, each participant was asked to comment on the following two questions:

1. Have you found the wetland restoration project on your property beneficial to your operation?
2. Have you found VRI technology to be beneficial?

Question 1

Producer 1 found the wetland restoration beneficial in providing income from grazing on the wetland area. Producer 2, as demonstrated above, could have reaped the benefits of grazing. Producer 1 said the grazing helped manage the vegetative growth on the wetland area, and the cattle producer renting Producer 1's grazing area found that their feed input costs associated with the cattle decreased for that period of time. Producer 1 also found that new wildlife moved into the area, which contributed to a social benefit from the land. Producer 1 also mentioned that it seemed like they were saving on water, although the quantitative data does not confirm this. Producer 2 noted that there was a great benefit from being able to pass through the wetland area without getting the pivot stuck in the soil.

Question 2

Producer 1 found that the VRI technology in year 1 was more beneficial than year 2 due to weather conditions. With 2017 being a relatively wet year, Producer 1 did not have the chance to fully utilize the technology and the crop prescriptions offered by the irrigation experts – CropMetrics and AgSense.

Producer 1 mentioned the technology being more beneficial in a dry year when water can be applied more precisely in desirable areas of the field based on the results from the software programs. Another comment provided by Producer 1 was the advantage of the individual sprinkler heads on the VRI system to shut off in low-lying areas (i.e. wetlands, depressions in the landscape, etc.), which helped limit over-watering.

One disadvantage Producer 1 found with the prescription mapping was the minimal amount of training offered for the software. Producer 1 said if more training was offered, it would have made the software more user-friendly and convenient. Consequently, Producer 1 gained a lot of valuable knowledge about the application through a more hands-on learning experience.

These points may be one producer's opinion, but they highlight an important aspect of the planning methods that need to be considered when making decisions about the types of assistance that should be offered to participants. Evans et al., (2013) discuss many of the challenges with increasing VRI adoption. Among the many solutions they offer are to provide basic prescriptions, optimal placement of various non-mobile sensor systems, and technical assistance and training (Evans et al., 2013). This is also in-line with the earlier discussion regarding the direct relationship between experience and benefits from VRI. Perhaps a more collaborative planning approach would include ensuring that the producers had the training beforehand to optimize their success.

This assistance could be taken even further with the addition of upfront cost-share assistance for prescription mapping to show producers the true potential their field actually has with VRI. Jake LaRue and Robert Evans (2012), discuss the concept of field variability rating which is the portion of a given field that is not being properly irrigated due to soil or topographic conditions. Knowledge of field variability prior to investing would be invaluable information in determining if an investment is economically feasible. Planners may consider taking this approach when encouraging producers to adopt.

Another comment from Producer 1 is related to this discussion. Although training would have been appreciated for the new software, Producer 1 was already somewhat educated about soil probes, and had already installed them prior to this project. However, as the terms of the project required installation of specific probes, they were an additional cost that was viewed as unnecessary by the producer. If the preliminary assessment of the project had included advanced soil mapping, it may have been determined that the additional probes were unnecessary.

Producer 1 also mentioned that a person who has other career obligations may find this technology much more beneficial and convenient, with the ability to remotely shut off and turn on the pivot or see how the field is changing throughout the season via a phone or computer.

Producer 2 believed weather conditions greatly affected the outcome of the crop. Producer 2 also had difficulty with a hybrid seed that did not produce desirable results in the first year using VRI. This contributed to a lack of quality data for VRI in the first year. However, the situation provided a real-world example of the unpredictability of critical variables within farming operations. While a year like this goes against historical trends, it is those historical trends that can be looked to for confidence in recovering from such difficult years.

Despite the inconclusive nature of the data regarding water usage, Producer 2 found the soil probes to be of great benefit, especially with the aid of the VRI prescription mapping to help manage the field. Producer 2 said the soil probes will likely contribute to higher yields in the future when some of the other logistical factors are sorted out. Producer 2 explained that there were mechanical, prescription, and mapping issues that needed to be addressed in order to see the full benefit from the VRI system. Again, this goes back to my discussion of preliminary training and mapping that would have improved this experience for Producer 2.

There are four important takeaways from this qualitative data. One is that both producers agreed it was difficult to offer an informed answer about whether or not VRI was found to be more beneficial in the second year compared to the first year, due to market and weather conditions effecting the outcome of their operations. Another takeaway is that social benefits might outweigh some of the financial benefits for a producer that is concerned with conservation or that wishes to use the land for recreational purposes. Additionally, the convenience and less effort that's required when using this system can create more leisure time. The final takeaway is that environmental and economic planning professionals may have a vital role in the implementation of projects similar to this. They could provide the methodology for ensuring that all stakeholders are collaborating in a way that is meaningful.

CHAPTER 5: Limitations & Recommendations

There were many limitations to this project that had a significant effect on the VRI benefit assessment. The most notable being the number of participants. With only five participants, two of those being the retrofitted sites, and the remaining three being unaltered control sites; the quantity of the information collected was minimal. Then, the quality of the data from the control sites was invalidated by uncontrollable factors. Overall, the data from the retrofitted sites was useful, but involving more producers would have aided in the accuracy of this study.

One factor that led to resistance among participant involvement was the type of information that was being collected. Financial and performance records are considered confidential information that most producers are reluctant to provide. This made the data collection portion of this project very challenging. One of the methods used to get in contact with producers was reaching out to Resource Conservationists at NRDs throughout the RWB. This was helpful in identifying potential participants that might participate, but it was limited because of the lack of producers answering phone calls or responding to letters in the mail. A high financial incentive for participants may have helped with increasing participation.

Another limitation was obtaining the correct contact information for participants identified as viable candidates. Much of the contact information from the NRDs was no longer valid. This created a very difficult situation in trying to increase the number of participants. In the future, one way to increase the connection with producers would be to try different approaches such as contacting local cooperatives or irrigation experts who work directly with the producers, and to have them help set up meetings with the producers and the research team. Face-to-face meetings can aid tremendously in research involvement and ease the process in contacting producers who already have a relationship established with one of these groups.

As mentioned above, gaining security clearance to gather valid contact information contested my ability to get in contact with some producers. Phone numbers are considered proprietary information that cannot always be disclosed from the NRDs in Nebraska without the consent of the producers. Our experience showed that gaining proper contact information and face-to-face meetings would have increased participation in this research.

Although this study shows real-world data from participants using this technology, there are variables that cannot easily be controlled based on the variability of the land. Specific biological land characteristics, such as different soil types, wetland footprint areas, and acreage, can make it difficult to provide valid comparisons. These variables were considered a limitation in this study because no two parcels of land are exactly alike. Future research studies could incentivize specific types of fields that are needed for comparison sites to ensure producers collect and record the data required for the study.

Another aspect of this research that was difficult to account for was the behavioral responses that participants had to the volatile market and weather conditions. For example, it was extremely difficult to predict that a producer might decide to grow a different crop due to fluctuations in the market. The operator of one potential control site chose to grow a different crop in 2017, making a comparison impossible.

Joel J. Jones (Photographer). (1987-2018). 2016. Gift of the photographer.

Another limitation was the lack of precise hydrologic information. The collection of data regarding irrigation application, including the frequency and total amount of water applied, was difficult to obtain. A majority of the participants did not have detailed information regarding their water usage, and some participants had irrigation district water use where the producers paid a set amount each season. Installing a flowmeter to monitor water usage would help to provide accurate irrigation application rates. With more accurate information about water usage, it would have been possible to determine if water consumption levels were being affected by VRI.

Additionally, some of the participants did not have detailed information about labor, maintenance, and machinery costs. This posed a significant challenge that was off-set by using a total expense for each of these categories. More detailed information would have allowed this study to more readily analyze the changes in specific variables affecting the potential benefits of investing in VRI.

I. Implications for Environmental & Economic Professional Planners

Professional planners that deal with environmental and economic issues have to wear many hats that require them to adapt their methods to each new situation. Throughout this project there have been many opportunities to utilize planning that may or may not have been realized. I have repeatedly demonstrated how different topics relate to planning throughout this study. However, the one planning theory I found most useful was collaborative planning.

Throughout this project I utilized collaborative planning by interacting with private and public agencies to obtain information regarding VRI data, potential participants, and security clearance to collect confidential information. This became more elaborate as I started to design and perfect the data collection form and import the information into the Crop Enterprise Budgets.

Attachment C in the Appendix shows an example of the Crop Enterprise Budget used for this analysis. This example shows the true capability associated with these enterprise budgets and how they could be used to help producers make more informed decisions about their operation. With more specific information regarding crop input costs, the analysis portion of this project could have been expanded. Many producers do not keep meticulously detailed records for all of their crop input costs; but the usefulness of those records could help them increase their net farm income overtime by more closely evaluating those costs. These Crop Enterprise Budgets are one tool that could be used to achieve this, and environmental or economic planners could assist producers in this endeavor.

CHAPTER 6: Conclusion

This study serves as a foundation for examining the economic impacts of VRI technology and wetland restoration efforts. It provides a real-world example of how this technology may be a feasible investment for some producers and not for others because of each producer's specific situation. This study illustrates the importance of analyzing the marginal and social costs and benefits associated with upgrading a pivot system and restoring a wetland area to determine if the investment is warranted.

This study also evaluated the different levels of cost-share assistance that were an integral part in other producers deciding whether or not to participate. Those scenarios that showed a shorter payback period for these participants could also be indicators of possible methodologies for future producers that may not have as much assistance. It may also be useful information for those trying to determine what cost-share assistance is appropriate.

Furthermore, producers who participated in this study were able to gain valuable knowledge about their land and the effects a particular type of precision irrigation technology could have on their operation. This benefit is paramount in a world that has an increasingly high demand for food and an ever-changing, unpredictable climate. Although the two producers may disagree on the usefulness of the precision technology during the first two years of implementation, my analysis shows that both have reasonable expectations of more positive results in the future.

Further research examining the costs and benefits associated with adopting this technology and implementing conservation efforts is necessary to show the realized impact this technology can have on net farm income. Increasing the longevity and quantity of research studies similar to this will be necessary to determine what specific input cost variables are being affected by VRI. This project provides an example for environmental and economic planners that want to take part in helping to narrow the gap that currently exists among agricultural practices and conservation efforts.

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APPENDIX:

Attachment A: Invitation Letter Sent to Producers

Nebraska
UNIVERSITY OF
Lincoln

INSTITUTE OF AGRICULTURE AND NATURAL RESOURCES
DEPARTMENT OF AGRICULTURAL ECONOMICS

Name
Address
Address

Dear XXXX,

My name is Hannah Janda, I'm part of an interagency research study with the **Rainwater Basin Joint Venture program, Natural Resource Conservation Service**, the **University of Nebraska-Lincoln** and the **Nebraska Game and Parks Commission**. Our study involves evaluating the economic feasibility of integrating restored wetlands and variable rate irrigation technology.

Your property located in XXXX County was identified as one of a limited number of candidates that have the characteristics to serve as a control site for our study. If you are willing to participate in this study, we will ask about a number of characteristics within your operation, including land use, yields, and production costs.

Any information that you share with us will be averaged with other people's information to keep it completely confidential. An example of the data collection form packet we would ask you to fill out is accompanied with this letter.

If you choose to participate in this study, you will be entered into a drawing for a ***$100 gift card*** to either Cabela's or Amazon (winner's choice). Due to the small number of participants in this study, the odds of winning are reasonably good.

Please review the packet and let us know if you would be interested in taking part in this ground-breaking research. Your role would be critical in comparing whether or not wetland restoration and variable rate irrigation technology are profitable options for producers to implement on productive lands.

If you are interested, please contact me at 402-XXX-XXXX or hannah.janda.efp@gmail.com or Karina Schoengold at 402-472-2304 or kschoengold2@unl.edu.

SINCERELY,

PROFESSOR KARINA SCHOENGOLD
AGRICULTURAL ECONOMICS

Hannah Janda

HANNAH JANDA
GRADUATE RESEARCH ASSISTANT

102 H.C. Filley Hall / P.O. Box 830922 / Lincoln, NE 68583-0922 / (402) 472-3401 / FAX (402) 472-3460

Attachment B: Data Collection Form

DATA COLLECTION FORM

Directions: Please answer the following questions as completely as possible and fill out ONE form for EACH year. We would like to collect at least THREE years of historical records. Since yield and market conditions vary, multiple years of data are essential to provide a good representation of your net farm income.

Please skip any questions that are not applicable to your operation. For example, if you do not have livestock, the questions about feed and livestock labor costs are not relevant. However, the questions about income from rented grazing land may be relevant to your operation. If any portions of your operation are custom, please note that and provide the unit cost per acre or total expense for that input.

University of Nebraska-Lincoln

NOTE: *BY PARTICIPATING IN THIS STUDY YOU WILL BE ENTERED INTO THE DRAWING FOR A* ***$100 GIFT CARD.*** *DUE TO THE SMALL NUMBER OF PATICIPANTS, THE ODDS OF WINNING ARE HIGH!*

Karina Schoengold

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University of Nebraska Lincoln

University of Nebraska-Lincoln Department of Agricultural Economics

Rainwater Basin Joint Venture

NOTES: VRI = Variable Rate Irrigation

I. General Information

1. **Name and contact information**

Name:	
Phone:	
Address:	
Email:	

2. **What year is this information for?**

3. **What was your average labor cost (per hour)?**

4. **What was your average cost of diesel fuel (per gallon)?**

II. Crop Land Use

5. **Crop(s) Produced:** Questions 5 - 10 refer to each crop by 1, 2, and 3. Please leave the spaces blank if the question is not applicable to your operation.

	Crop Name	Average Revenue per Bushel or Ton
Crop 1		
Crop 2		
Crop 3		

1

6. **Total Acres** (please note if the harvested acreage is different than the planted acreage).

		Crop 1	Crop 2	Crop 3
Dryland Acres	Planted			
	Harvested			
VRI Irrigated Acres	Planted			
	Harvested			
Non-VRI Irrigated Acres	Planted			
	Harvested			

7. **Average Yield on Harvested Acres**

	Crop 1	Crop 2	Crop 3
Dryland Yield			
VRI Irrigated Yield			
Non-VRI Irrigated Yield			

8. **Crop Land Rented from Other Landowners (acres):** If all land is rented for cash rent leave the crop-share blank. If you have a crop-share agreement, describe the owner/operator share percent.

	Irrigated	Dryland
Acres Rented from Others		
Rental Rate per Acre (OR)		
Crop-share Agreement		

9. **Do you rent any land TO other producers?**
Please Circle: YES NO
If yes, how much revenue do you earn from rental payments? Explain.

2

III. Farm Irrigation Input Costs

10. Labor Expenses for Irrigation (if different from overall labor costs)

Annual Hours	
Annual Expenses	

11. Energy Costs for Irrigation: Fill in one column for each type of energy/fuel used for irrigation. (***Note:*** *If Natural Gas please indicate the unit (i.e. mcf or therms).*

	Non-VRI Irrigated Fields		**VRI Irrigated Fields**	
Energy/Fuel Type (circle the energy source)	Electricity Diesel N. Gas Other (list):	Electricity Diesel N. Gas Other (list):	Electricity Diesel N. Gas Other (list):	Electricity Diesel N. Gas Other (list):
Number of Acres Irrigated				
Annual Energy Cost				

12. Irrigation Application

	Non-VRI Irrigated Fields			**VRI Irrigated Fields**		
	Crop 1	**Crop 2**	**Crop 3**	**Crop 1**	**Crop 2**	**Crop 3**
Frequency (irrigation cycles per season)						
Total Water Applied per Acre						

13. Non-VRI Irrigation Type (fill in one column for each type/age of non-VRI irrigation system currently used)

Irrigation System Description			
Year Installed			
Number of Acres			

3

14. **VRI Irrigation Type** (fill in one column for each type/age of VRI irrigation system currently used)

Irrigation System Description			
Year Installed			
Number of Acres			

IV. Crop Input Costs

15. **Seed Costs:** There is space for two types of seed. If you use more than two types of seed for one crop please note the information next to the columns or on a separate page.

	Crop 1		**Crop 2**		**Crop 3**	
	Type 1	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**
Name of Seed						
Acres Applied						
Total Price						

16. **Fertilizer:** There is space for two types of fertilizer. If you use more than two types of fertilizer please note the information about the other types next to the columns or on a separate page.

	Crop 1		**Crop 2**		**Crop 3**	
	Type 1	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**
Please Circle One	Nitrogen Phosphorous Other: ___	Nitrogen Phosphorous Other: ___	Nitrogen Phosphorous Other: ___	Nitrogen Phosphorous Other: ___	Nitrogen Phosphorous Other: ___	Nitrogen Phosphorous Other: ___
Cost per Acre						
Acres Applied						

4

17. **Other chemicals** *(i.e. herbicide, insecticide, fungicide).* Please include the cost of all chemical inputs *other than fertilizers*. Fill in more than one column if your chemical use per acre varies across your farm. If you have more than two management plans, please note the cost and acres next to the columns, on the back of the page, or on a separate page.

	Crop 1		Crop 2		Crop 3	
	Type 1	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**
Please Circle One	Herbicide Insecticide Fungicide Other: ___	Herbicide Insecticide Fungicide Other: ___	Herbicide Insecticide Fungicide Other: ___	Herbicide Insecticide Fungicide Other: ___	Herbicide Insecticide Fungicide Other: ___	Herbicide Insecticide Fungicide Other: ___
Cost per Acre						
Acres Applied						

V. Cattle Management:

18. **Grazing Fees**

	Grazing Fees EARNED From Other Producers	Grazing Fees PAID To Other Landowners
Fee per Acre		
Acres Rented		

Please answer questions 19-23 for cow-calf or backgrounding operations. Feedlot costs should not be included.

19. **Annual Feed Costs by Type**

Type	**Grain (e.g., corn)**	**Residue**	**Additional Grazing Costs** (not fees earned or paid)	**Hay**
Total Cost				

20. **Labor Expenses for Cattle Management**

Total Hours		**Total Expenses OR Dollars per Hour**	

5

21. **Gas, Fuel, and Oil expenses for Cattle Management**

Gallons of Fuel		**Total Expenses**	

22. **Cattle Revenue**

Average Revenue per Head		**Number of Animals Sold**	

23. **Type & Amount of Cattle Owned** (i.e. weaned and yearling steers)

Type	Quantity

VI. Machinery Costs

NOTE: If you do not have separate machinery costs, please note the total annual cost for your equipment in QUESTION 27.

24. **Annual Costs for Owned Equipment:** Fill out the following for any OWNED machinery

	Cultivator	Combine	Tractor	Drill	Grain Cart
Annual Cost					

25. **Rental/Lease Costs:** Fill out the following table for any RENTED/LEASED machinery. Fill out the 'Number of Days' and 'Rental Rate' for rented equipment. Fill out the 'Lease Rate' for leased equipment.

	Cultivator	Combine	Tractor	Drill	Grain Cart
Number of Days					
Rental Rate (per day) OR					
Lease Rate (per year)					

26. **Maintenance:** Please note the annual repair costs for other equipment NOT LISTED in Questions 27-28.

Annual Cost	

27. **Total Annual Cost for Machinery:**

Annual Cost	

VII. Annual Management, Overhead, and Other Expenses

28. **Employee Benefits**

Gross annual cost	

29. **Utilities**

Total Annual Cost	

30. **Crop/Management Consulting Fees**

Total Annual Cost	

31. **Labor expenses NOT for Irrigation Management or Livestock Management**

Total Hours	
Total Expenses OR Dollar per Hour	

32. **Gas, Fuel, and Oil expenses NOT for Irrigation Management or Livestock Management**

Number of Gallons		
Please Circle One	**Average Price per Gallon OR Total Expenses**	

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33. **Property Taxes for Irrigated and Non-Irrigated Land** (schedule Fs or Form 1120s are most useful)

	Irrigated	Non-Irrigated
Number of Acres		
Average Cost per Acre		
Total Cost		

34. **Crop Insurance Enrollment Level for Irrigated & Non-Irrigated Crops** (if your coverage varies by crop, please list the coverage for each crop separately)

		Crop 1	Crop 2	Crop 3
Type of Coverage (e.g., yield, revenue)	Irrigated			
	Non-Irrigated			
Coverage Level	Irrigated			
	Non-Irrigated			
Acres Covered	Irrigated			
	Non-Irrigated			
Average Per-Acre Premium	Irrigated			
	Non-Irrigated			

35. **Other Costs (i.e. irrigation, crop inputs, machinery, or cattle) not mentioned.** Please add rows or list items on the back of the page if necessary.

Item	Annual Cost
1.	
2.	
3.	

Thank you for completing this form. You will be entered into the drawing for ***$100 gift card***. Please use the prepaid envelope to return the information to the address below at your earliest convenience.

Karina Schoengold
307A Filley Hall
University of Nebraska
Lincoln, NE 68583-0922

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Attachment C: Snapshots of the Enterprise Budget used to analyze the data collected from participants.

Crop Inputs

		Income				Rent		Owned Real Estate		
Enterprise	Acres Farmed	Yield	Crop	Price	$ Crop Residue	Cash / Acre	Land Share	Acres	Taxes / Acre	Other Exp / Acre
Corn Irrigated VRI - 28	130	225	Corn	3.50			50%		24	7
Corn Irrigated Non-VRI - 28	130	225	Corn	3.50		300			24	6
Corn Dryland Share - 18	110	125	Corn	3.50			50%		14	5
Corn Dryland Cash - 18	110	125	Corn	3.50		150			14	4
Soybeans Irrigated VRI - 51	130	65	Soybeans	9.00			50%		24	3
Soybeans Irrigated Non-VRI - 51	130	65	Soybeans	9.00		300			24	8
Soybeans Dryland Share - 47	110	43	Soybeans	9.00			50%		14	9
Soybeans Dryland Cash - 47	110	43	Soybeans	9.00		150			14	1
Wheat Irrigated VRI - 67	130	85	Wheat	5.00			50%		24	
Wheat Irrigated Non-VRI - 67	130	85	Wheat	5.00		300			24	
Wheat Dryland Share - 61	110	45	Wheat	5.00			50%		14	
Wheat Dryland Cash - 61	110	45	Wheat	5.00		150			14	
Cover Crop - 69	110			0.00	40					
				0.00						
				0.00						
				0.00						
				0.00						
				0.00						
				0.00						
				0.00						

Field Operations

Operation Description	Unit	Units per Da	Gallons Fuel per Day	Hours per Day	Hours per Unit	Gallons of Fuel per Unit
Anhy Apply (supplier)	acre	100	65	10	0.10	0.65
Anhydrous Apply	acre	85	65	10	0.12	0.76
Cart	bushel	34000	70	10	0.00	0.00
Chisel	acre	100	80	10	0.10	0.80
Chop Silage	Custom					
Chop Stalks	acre	125	60	10	0.08	0.48
Combine Dryland Corn	acre	70	100	10	0.14	1.43
Combine Dryland SB	acre	65	100	10	0.15	1.54
Combine Dryland SG	acre	65	100	10	0.15	1.54
Combine Irr Corn	acre	70	100	10	0.14	1.43
Combine Irr Dry Beans	acre	50	100	10	0.20	2.00
Combine Irr SB	acre	60	100	10	0.17	1.67
Combine Irr SG	acre	65	100	10	0.15	1.54
Combine Small Grain	acre	70	100	10	0.14	1.43
Combine Sunflowers	acre	70	100	10	0.14	1.43
Corrugate	acre	70	50	10	0.14	0.71
Disc	acre	110	80	10	0.09	0.73
Ditch Irrigation	acre-inch	18	0	10	0.56	0.00
Double Windrows	acre	200	20	10	0.05	0.10
Drill	acre	75	50	10	0.13	0.67
Drill w/ Fertillizer	acre	70	50	10	0.14	0.71
Dry Grain	bushel	10000	200	2	0.00	0.02
Fallow Master	acre	150	90	10	0.07	0.60
Field Cultivation	acre	150	80	10	0.07	0.53
Grass Drill	acre	60	40	10	0.17	0.67

Material Cost, Field Labor, and Custom Hire

Material	Category	Purchase Price	Purchase Unit	Applied Unit	Applied Units / Purchased	Applied Price
10-34-0	Fertilizer	$3.30	gallon	gallon	1	$3.30
10-34-0-1Z	Fertilizer	$3.35	gallon	gallon	1	$3.35
11-52-0	Fertilizer	$0.30	pound	pound	1	$0.30
2,4-D Amine	Herbicide	$16.00	gallon	pint	8	$2.00
2,4-D Ester 4#	Herbicide	$24.50	gallon	pint	8	$3.06
21-0-0-24S	Additive	$0.33	pound	pound	1	$0.33
28-0-0	Fertilizer	$1.70	gallon	lbs N	3	$0.57
32-0-0	Fertilizer	$0.55	lbs N	lbs N	1	$0.55
32-0-0 (Applied by Pivot)	Fertilizer	$0.55	lbs N	lbs N	1	$0.55
32-0-0 (Applied by R2)	Fertilizer	$0.55	lbs N	lbs N	1	$0.55
32-0-0 (Q)	Fertilizer	$1.95	gallon	quart	5	$0.39
46-0-0	Fertilizer	$0.57	lb N	lbs N	1	$0.57
82-0-0	Fertilizer	$0.46	lb N	lbs N	1	$0.46
AAtrex 4L	Herbicide	$21.00	gallon	quart	4	$5.25
Aerial Spray	Custom	$9.50	acre	acre	1	$9.50
Aim 2EC	Herbicide	$240.00	quart	ounce	32	$7.50
Alfalfa RR w/ Inoculant	Seed	$9.00	pound	pound	1	$9.00
Alfalfa w/Inoculant	Seed	$6.00	pound	pound	1	$6.00
Ally Extra SGW/TOTSOL	Herbicide	$9.00	ounce	ounce	1	$9.00
Asana XL	Insecticide	$80.00	gallon	ounce	128	$0.63
Atrazine 90 DF	Herbicide	$3.25	pound	pound	1	$3.25
Authority First DF	Herbicide	$90.00	pound	ounce	16	$5.63
Balance Flexx	Herbicide	$6.00	ounce	ounce	1	$6.00
Bale Lg Sq 1570 lb	Custom	$13.00	bale	ton	1	$20.00
Basagran	Herbicide	$105.00	gallon	pint	8	$13.13
Bicep II Magnum	Herbicide	$50.00	gallon	quart	4	$12.50

Cash Analysis

Irrigation Inputs

Water Source	Well	Well			
Irrigation District, $/acre					
Pumping water level, ft.	140	150			
Select Distribution System Type	Sprinkler	Sprinkler			
System Pressure, PSI	45	45			
System Capacity (acre-inches/day)	65	65			
System Effeciency Adjustment	1	0.9			
Select Power Unit Type	Electric	Diesel			
Electricity Annual Fee	500				
Electricity Use Charge per Kwh	0.1				
Propane					
Natural Gas Price ($/MCF)					
Natural Gas Price ($/Therm)					
Acres Irrigated	130	130			
Average Inches Applied	10	10			
Hours Labor per Day of Operation	1	1			
Hours Labor Beg and End Year	10	10			

per Season Totals

Labor Hours	30.00	30.00	0.00	0.00	0.00
Energy Units	40,721	2,701	0	0	0
Labor Costs	600	600	0	0	0
Diesel	0	8,103	0	0	0
Electric	4,572	0	0	0	0
Propane	0	0	0	0	0
Natural Gas MCF	0	0	0	0	0
Natural Gas Therm	0	0	0	0	0
Irrigation District Charge	0	0	0	0	0

per Acre-inch

Labor Hours	0.02	0.02	0.00	0.00	0.00
Energy and Fees	3.52	6.23	0.00	0.00	0.00

Cash (Financial) Summary

		Gross Income		Cash Expenses		Net Income		
Index	Name	Enterprise	per Acre	Enterprise	per Acre	Enterprise	per Acre	Break Even
1	Corn Irrigated Share - 28	51,188	394	64,631	497	-13,444	-103	4.42
2	Corn Irrigated Cash - 28	102,375	788	122,432	942	-20,057	-154	4.19
3	Corn Dryland Share - 18	24,063	219	23,543	214	520	5	3.42
4	Corn Dryland Cash - 18	48,125	438	45,529	414	2,596	24	3.31
5	Soybeans Irrigated Share - 51	38,025	293	29,886	230	8,139	63	7.07
6	Soybeans Irrigated Cash - 51	76,050	585	82,399	634	-6,349	-49	9.75
7	Soybeans Dryland Share - 47	21,285	194	17,981	163	3,304	30	7.60
8	Soybeans Dryland Cash - 47	42,570	387	38,578	351	3,992	36	8.16
9	Wheat Irrigated Share - 67	27,625	213	32,574	251	-4,949	-38	5.90
10	Wheat Irrigated Cash - 67	55,250	425	83,802	645	-28,552	-220	7.58
11	Wheat Dryland Share - 61	12,375	113	15,845	144	-3,470	-32	6.40
12	Wheat Dryland Cash - 61	24,750	225	38,017	346	-13,267	-121	7.68
13	Cover Crop - 69	4,400	40	5,428	49	-1,028	-9	
14								
15								
16								
17								
18								
19								
20								
Total		528,080	341	600,644	388	-72,564	-47	

Profit (Economic) Summary

Gross Income		Cash Expenses		Net Income	
Enterprise	per Acre	Enterprise	per Acre	Enterprise	per Acre
51,188	394	73,382	564	-22,194	-171
102,375	788	134,333	1,033	-31,958	-246
24,063	219	25,024	227	-961	-9
48,125	438	48,490	441	-365	-3
38,025	293	37,826	291	199	2
76,050	585	92,679	713	-16,629	-128
21,285	194	19,291	175	1,994	18
42,570	387	41,198	375	1,372	12
27,625	213	39,874	307	-12,249	-94
55,250	425	92,802	714	-37,552	-289
12,375	113	16,607	151	-4,232	-38
24,750	225	39,540	359	-14,790	-134
4,400	40	5,699	52	-1,299	-12
528,080	341	666,744	430	-138,664	-89